Coastal Engineering Technical Note

COMPUTER PROGRAM
TWAVE2 - WAVE REFRACTION AND SHOALING

PROGRAM PURPOSE: To refract and shoal waves in terms of directional wave energy spectra into shallow water for simple bathymetry.

BACKGROUND: In the past, most refraction models have dealt only with monochromatic waves. Increasing interest in directional spectra has created a need to quantify the effects of refraction on directional spectra. This program uses Snell's law to refract a specified spectrum over straight, parallel bottom contours to a given depth. The user inputs parameters which describe a spectrum in deep or shallow water. Some simplifying assumptions have been made because of the complexity of the problem. These assumptions impose severe limitations on the application of this model. This model is not meant to replace the more complex numerical models used in most design studies. The more complex models give greater flexibility because fewer assumptions are made, but they require more time and expense to develop model input and are more expensive to run. TWAVE2 should be used as a quick, first estimate of wave conditions.

ASSUMPTIONS:

1. Only active wind seas are considered, swell is excluded.
2. Straight, parallel bottom contours.
3. Gentle slope up to 1:100.
4. No interactions with currents, structures, etc... .
5. $\cos^4$ spreading function for directions (CETN-I-28).
6. Each frequency component is treated independently, according to linear theory.

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
DEC 1985		**00-00-1985 to 00-00-1985**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Computer Program Twave2-Wave Refraction And Shoaling	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U. S. Army Engineer WaIemays Experiment Station,Coastal Engineering Rmarch Center,P. 0. Box 631,Vicksburg,MS,39180**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

In the past, most refraction models have dealt only with monochromatic waves. Increasing interest in directional spectra has created a need to quantify the effects of refraction on directional spectra. This program uses Snell's law to refract a specified spectrum over straight parallel bottom contours to a given depth. The user inputs parameters which describe a spectrum in deep or shallow water. Some simplifying assumptions have been made because of the complexity of the problem.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**8**	

7. The peak frequency remains constant during shoaling.
8. Waves generated locally by wind, i.e. wave energy to high frequency side of spectral peak is limited by the JONSWAP spectrum (Hasselmann et al., 1973) in deep water and by the TMA depth-limited spectrum in shallow water (Hughes, 1984).

INPUT: The program takes all input interactively. The program asks the user questions that can be answered yes, no, or numerically. Numeric answers should be entered in free format, meaning a string of numbers can be entered on one line separated by commas, or each number can be entered followed by a carriage return. The program prompts with a question mark on a new line for input. Default values which are provided for some input parameters are listed and the user has the opprotunity to change the values. The input required included:

1. Units. The user is asked to choose metric or English and degrees or radians for units. All input must be given in the specified units. All output will also be given in the specified units.
2. Spectral frequency bands. The user must choose an initial frequency, a frequency band width, and the number of frequencies desired (10 or 20). Defaults are provided.
3. Type of input: The user has a choice of 5 types of input:
   a. deepwater--JONSWAP parameters
   b. deepwater--over water wind speed at 10-m (33-ft) elevation and fetch
   c. deepwater--real spectrum (user-specified)
   d. shallow water--energy-based significant wave height (Hmo), peak frequency, and depth
   e. shallow water--over water wind speed at 10- m (33-ft) elevation, peak frequency, and depth

   The Shore Protection Manual (SPM, 1984) gives expressions to convert wind speeds to the 10-m elevation and over land wind speeds to over water wind speeds. The program converts input wind speeds to wind-stress factors internally to account for the nonlinear relationship between wind stress and wind speed (SPM, 1984).
4. Output depths. The user specifies depths at which output is desired. The user designates the first depth and the depth decrement. The first depth must be greater than or equal to 10 times the

depth decrement and less than the input depth (or less than 1000 m for deepwater input).

5. Wave approach angle. The approach angle is in 10 degree sectors, i.e. an angle between -5 degrees and 5 degrees is represented by 0 degrees, and an angle between 5 degrees and 15 degrees is represented by 10 degrees. An angle of 0 degrees represents a wave approaching normal to the shore.

6. Full print. A full print consists of a summary of wave heights, nondirectional energy spectra, and directional spectra at specified depths. The other option is only the summary of wave heights.

7. Multiple runs. This option allows the user to loop through the program as many times as desired. The output from each run is added to the end of the output file. This option is only applicable if a full print output is specified.

OUTPUT: The program output is a local file called TAPE6. The output includes a summary of wave heights, nondirectional spectra, and directional spectra at the specified depths. The program explains how to look at this file and also how to plot HMO vs DEPTH and ENERGY DENSITY vs DEPTH if the user has access to a TEKTRONICS graphics terminal. The output is illustrated in the following sample problem.

SAMPLE PROBLEM: Underlined values are the user's input. User input marked with * are specific to the Control Data Cybernet DOE family.

```
GET,TWAVE2/UN=CEROI7                *
/FTN,I=TWAVE2,L=0                   *
AEB ,      0.254UNTS.
/LGO                                *
  THIS PROGRAM DEFAULTS TO METRIC UNITS
     VELOCITY(M/S), LENGTH(M), ENERGY DENSITY(M*M*S)
  DO YOU WANT INPUT AND OUTPUT IN ENGLISH UNITS? (Y OR N)
     VELOCITY(FT/S), LENGTH(FT), ENERGY DENSITY(FT*FT*S)
? N


  MEAN WAVE ANGLE IS IN DEGREES
  DO YOU WANT MEAN WAVE ANGLE IN RADIANS? (Y OR N)
? N


  FIRST FREQ. IS THE INITIAL FREQUENCY(HZ)
     FREQ. BAND WIDTH IS THE WIDTH OF THE FREQUENCY BANDS
     NO. FREQ. IS THE NUMBER OF FREQUENCIES WANTED  (10 OR 20)

  THE CURRENT VALUES ARE:

  FIRST FREQ=    .060
  FREQ. BAND WIDTH=    .010
  NO. FREQ.= 10

  DO YOU WANT TO CHANGE THESE VALUES?  (Y OR N)
? N
```

```
   ENTER TYPE OF INPUT:

      DEEP WATER
        1 FOR JONSWAP PARAMETERS
        2 FOR WIND SPEED AND FETCH
        3 FOR REAL SPECTRUM

      SHALLOW WATER
        4 FOR ZERO MOMENT WAVE HEIGHT (HMO), FREQUENCY, AND DEPTH
        5 FOR WIND SPEED, FREQUENCY, AND DEPTH
 ? 1

   FM,ALPHA,GAMMA,SIG-A AND SIG-B ARE THE FIVE
      JONSWAP PARAMETERS

   THE CURRENT VALUES ARE:

      FM=    .100
      ALPHA=    .010
      GAMMA=  3.300
      SIG-A=    .100
      SIG-B=    .100

   DO YOU WANT TO CHANGE THESE VALUES?  (Y OR N)

 ? Y
   ENTER FM,ALPHA,GAMMA,SIG-A,SIG-B
 ? .11,.01,3.0,.1,.1

   DEL DEPTH IS DEPTH DECREMENTS(M)  AND DEPTH1 IS THE MAX OUTPUT DEPTH(M)
      DEPTH1 MUST BE GREATER THAN OR EQUAL TO DEL DEPTH * 10.

   THE CURRENT VALUES ARE:

   DEL DEPTH=    1.0
   DEPTH1=    10.0

   DO YOU WANT TO CHANGE THESE VALUES?  (Y OR N)
 ? N

   THETA IS THE WAVE APPROACH ANGLE(DEG)
      POSSIBLE VALUES OF THETA ARE -90.00 TO  90.00
      0.0 IS SHORE PERPENDICULAR, 90.00 IS SHORE PARALLEL

   THE CURRENT VALUES ARE:

   THETA=  10.00

   DO YOU WANT TO CHANGE THESE VALUES?  (Y OR N)
 ? N


          SIMPLE REFRACTION OF A DIRECTIONAL  WAVE SPECTRUM

            DEPTH                    HMO(M)
            10.00                     3.03
             9.00                     2.93
             8.00                     2.81
             7.00                     2.69
             6.00                     2.56
             5.00                     2.39
             4.00                     2.19
             3.00                     1.69
             2.00                     1.03
             1.00                      .44
```

```
      HMO(M) =  4.17  AT D(M) =1000.  FM(HZ)=.11
      ALPHA,GAMMA,SIG-A,SIG-B=  .0100  3.000   .100   .100
      THETA=  10.00



   DO YOU WANT FULL PRINT? (Y OR N)
? Y

     DONE
  DO YOU WANT TO MAKE ANOTHER RUN?          (Y OR N)
? N

   IF YOU WISH A HARD COPY OF THE DATA, TYPE IN
       REWIND,*
       LNH,F=TAPE6

   IF YOU WISH A PLOT OF THE DATA, TYPE IN:
       GET,TWPLOT/UN=CER017
       REWIND,*
       BEGIN,DISUNPF,DISPROC,C=TWPLOT
       BEGIN,UNIPOST,UNIPROC,D=TEK


    STOP
/REWIND,*                        *
   7 FILE(S) PROCESSED.
/LNH,F=TAPE6                     *
```

SIMPLE REFRACTION OF A DIRECTIONAL WAVE SPECTRUM

DEPTH	HMO(M)
10.00	3.03
9.00	2.93
8.00	2.81
7.00	2.69
6.00	2.56
5.00	2.39
4.00	2.19
3.00	1.69
2.00	1.03
1.00	.44

```
      HMO(M) =  4.17  AT D(M) =1000.  FM(HZ)=.11
      ALPHA,GAMMA,SIG-A,SIG-B=  .0100  3.000   .100   .100
      THETA=  10.00
```

SPECTRAL ENERGY DENSITY (M*M*S)
FREQUENCY(HZ)

DEPTH (M)	.06	.07	.08	.09	.10	.11	.12	.13	.14	.15	HMO(M)
1000.	.0	.2	2.2	7.9	20.5	33.0	21.2	10.8	7.3	5.7	4.2
10.	.0	.0	.7	3.1	10.7	22.4	8.9	4.8	3.7	3.2	3.0
9.	.0	.0	.6	2.9	10.0	21.2	8.2	4.5	3.4	2.9	2.9
8.	.0	.0	.6	2.6	9.3	19.4	7.7	4.1	3.1	2.7	2.8
7.	.0	.0	.5	2.3	8.5	18.0	7.0	3.7	2.8	2.4	2.7
6.	.0	.0	.4	2.1	7.7	16.3	6.4	3.3	2.5	2.2	2.6
5.	.0	.0	.4	1.8	6.7	14.3	5.5	2.9	2.2	1.9	2.4
4.	.0	.0	.3	1.5	5.6	12.0	4.6	2.4	1.8	1.6	2.2
3.	.0	.0	.2	1.0	3.4	6.9	2.8	1.5	1.1	1.0	1.7
2.	.0	.0	.1	.4	1.2	2.3	1.0	.6	.5	.5	1.0
1.	.0	.0	.0	.1	.2	.3	.2	.1	.1	.1	.4

MEAN WAVE ANGLE(DEG)
FREQUENCY(HZ)

DEPTH (M)	.06	.07	.08	.09	.10	.11	.12	.13	.14	.15	MEAN
10.	2.80	3.27	3.74	4.20	4.67	5.13	5.59	6.04	6.47	6.90	5.26
9.	2.66	3.10	3.54	3.99	4.43	4.87	5.31	5.74	6.16	6.57	4.99
8.	2.50	2.92	3.34	3.76	4.18	4.59	5.01	5.42	5.82	6.22	4.71
7.	2.34	2.73	3.12	3.52	3.91	4.30	4.69	5.07	5.46	5.84	4.40
6.	2.17	2.53	2.89	3.25	3.62	3.98	4.34	4.70	5.06	5.41	4.07
5.	1.98	2.31	2.64	2.97	3.30	3.63	3.96	4.29	4.62	4.95	3.71
4.	1.77	2.06	2.36	2.66	2.95	3.25	3.54	3.84	4.14	4.43	3.32
3.	1.53	1.79	2.04	2.30	2.56	2.81	3.07	3.32	3.58	3.84	2.87
2.	1.25	1.46	1.67	1.88	2.09	2.29	2.50	2.71	2.92	3.13	2.34
1.	.88	1.03	1.18	1.33	1.47	1.62	1.77	1.92	2.06	2.21	1.65

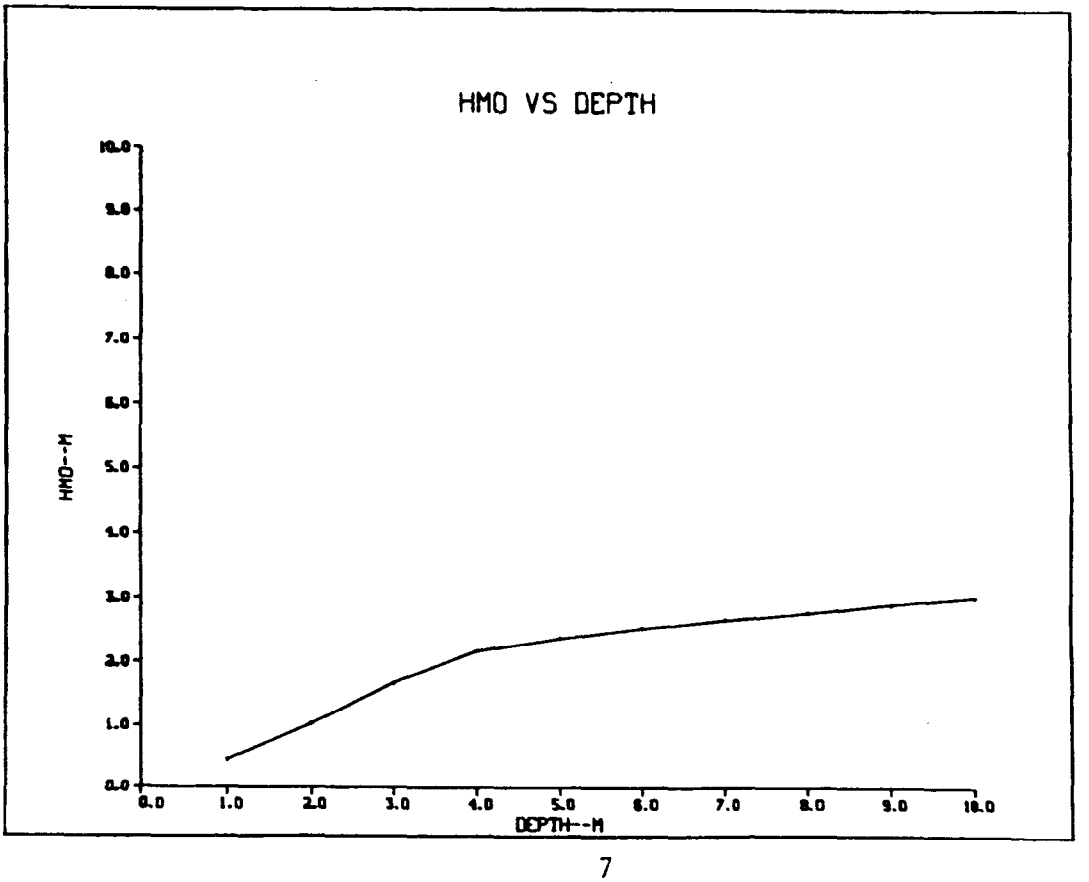
```
 EOI ENCOUNTERED.
/REWIND,*                    *
  7 FILE(S) PROCESSED.
/GET,TWPLOT/UN=CER017        *
/BEGIN,DISUNPF,DISPROC,C=TWPLOT   *
 UNIPLOT V3.2 R07 IS NOW THE DEFAULT.
 SEE EXPLAIN,UNIPLOT,NEWS FOR MORE INFORMATION.
 ************************************************
 *                                              *
 * UNIPLOT V3.2 LIBRARY REQUIRES FTN5 APPLICATION. *
 *                                              *
 * !!!!!!!!!!! PLEASE CONVERT TO FTN5 !!!!!!!!!!!! *
 *                                              *
 * FOR NOW, UNIPLOT V3.1 R04 LIBRARY WILL BE USED. *
 * IN OCTOBER 1985, FTN5 (F5) WILL BE THE DEFAULT. *
 *                                              *
 ************************************************
```

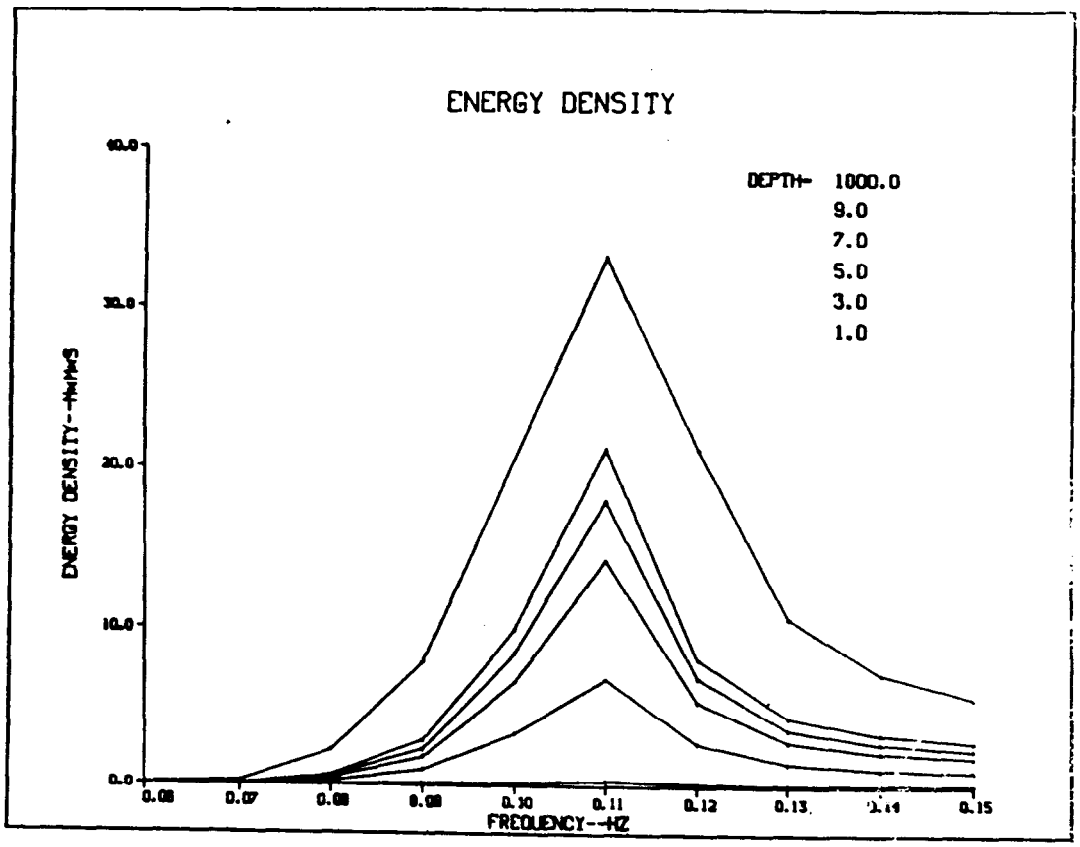
```
 END OF DISSPLA 8.2 --      2348 VECTORS GENERATED IN      2 PLOT FRAMES.
 -ISSCO-  4186 SORRENTO VALLEY BLVD.,SAN DIEGO CALIF. 92121

 DISSPLA IS A CONFIDENTIAL PROPRIETARY PRODUCT OF ISSCO AND ITS USE
    IS SUBJECT TO A NONDISSEMINATION AND NONDISCLOSURE AGREEMENT.

REVERT. DISUNPF PROCEDURE COMPLETE
/BEGIN,UNIPOST,UNIPROC,D=TEK       *
 UNIPLOT V3.2 R07 IS NOW THE DEFAULT.
 SEE EXPLAIN,UNIPLOT,NEWS FOR MORE INFORMATION.
 UNIPOST V3.2 RELEASE 07
 COPYRIGHT CONTROL DATA 1985
 AUTOMATIC HARDCOPY (Y/N)
? Y
 2 = 4010 ASYNCHRONOUS
 4 = 4014 ASYNCHRONOUS
 6 = 4014 EGM ASNCHRONOUS
 ENTER TERMINAL TYPE
? 4
 ENTER BAUD RATE
? 1200
```

The screen will go blank, then the first plot (HMO vs DEPTH) will be drawn. To view the second plot (ENERGY DENSITY vs FREQUENCY), enter a carriage return. The screen will again go blank and the second plot will be drawn. Another carriage return will clear screen.





AVAILABILITY: A FORTRAN listing of the program is available from the CERC Coastal Oceanography Branch. The program is internally documented via comment cards. The program is available for interactive use on the CYBERNET Services System. For further information, contact Jane McKee Smith at 601-634-2079

REFERENCES:

Hasselmann, K., et al. 1973. Measurements of Wind-Wave Growth and Swell Decay during the Joing North Sea Wave Project (JONSWAP)," Report No. 12, Deuthshes Hydrographisches Institut, Hamburg.

Hughes, S. A. 1984 (December). "The TMA Shallow-water Spectrum Description and Applications," Technical Report CERC-84-7 , US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Shore Protection Manual. 1984. 4th ed., 2 vols, US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, US Government Printing Office, Washington, DC.

US Army Corps of Engineers, Coastal Engineering Research Center. 1985. "Directional Wave Spectra Using Cos^2 and Cos(2s) Spreading Functions," CETN-I-28, Vicksburg, MS.